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IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

Current Sunspot Numbers

The choice of the period July 1957 to December 1958 for the International Geophysical Year was determined in part by the expectation that sunspot frequency would reach a cyclical maximum during this time. Since upper atmosphere effects would then be pronounced, coordinated geophysical studies could greatly increase knowledge of solar-terrestrial relationships. Of considerable scientific interest is the fact that recent sunspot numbers have attained an apparently unprecedented level. Pending final refinement of the data, the particular interval during which peak frequency is reached during the current cycle will not be known precisely. However, the present cycle, which began in 1954, had already reached a count of 169.6 in January 1957. Data reaching as far back as 1755 show no peak as high. The highest previous peak occurred in 1778 (*see Fig. 1*).

Even before the invention of the telescope and the use of that instrument for astronomical purposes, man had noted the appearance now and then of dark areas on the surface of the sun. Then, in 1612, Galileo trained his telescope on the sun and for the first time actually observed the spots in detail. He concluded that they were phenomena on the sun itself, rather than shadows of bodies external to the sun. He also observed the motions of the spots across the face of the sun and postulated that the sun rotates from east to west with a period of somewhat less than a month. Galileo made sunspot maps in 1612 that compare favorably with maps made today with modern small telescopes.

In the 19th century, Sir John Herschel said of sunspots, "Many fanciful notions have been broached on this subject, but only one seems to have any degree of physical probability, viz., that they are the dark, solid body of the sun itself, laid bare to our view. . ." Although astronomers now know that the sun is a gaseous body and has no dark, solid interior, the exact nature of sunspots and their relation to other phenomena on the surface of the sun are today matters of considerable scientific disagreement and discussion.

Since about 1749, sunspots have been observed on a regular basis. It was not until 1834, however, that a Swiss Astronomer, R. Wolf, of the Federal Observatory, Zurich, devised a standardized method which is still in use. Wolf's method takes into account the number of groups as well as of individual spots. The daily sunspot number, Rn, is determined as follows:

$$Rn = k(10g + s)$$

where g is the number of groups visible on the disc, s is the number of individual spots, and k is a constant adjusting the number for the "personal equation" of the observatory, taking into account average visibility, type

of equipment, variability between observers, etc. The sunspot number is determined daily by observatories throughout the world.

The daily numbers fluctuate widely and a first smoothing is obtained by averaging over a month. These monthly values are further smoothed by computing running means for a year, which gives the mean in the middle of the yearly period. Finally, two consecutive means are averaged, giving the Zurich number for a month. These final monthly numbers are shown in Fig. 1, extending back to 1755. It is seen from the figure that there is an average periodicity of somewhat more than 11 years, measured from minimum to minimum, but the individual cycles vary from about 9 to 13 years. The present collection and publication of sunspot numbers is being undertaken by the Swiss Federal Observatory, Zurich, under the direction of M. Waldmeier.

As can also be seen from the figure, the individual cycles vary considerably in the peak counts reached at the maximum; there is a factor of about three between the most active cycles and the least active ones. The last complete cycle was one of high activity. The maximum smoothed count, 151.8, occurred late in 1947. The present cycle, which began in 1954, had already reached a count of 169.6 in January (represented by a broken line on the graph). Unsmoothed counts from recent months have been large, especially for the period just before the IGY began officially, and it is conceivable that when the smoothed values are obtained they will show that the maximum actually occurred during this pre-IGY period.

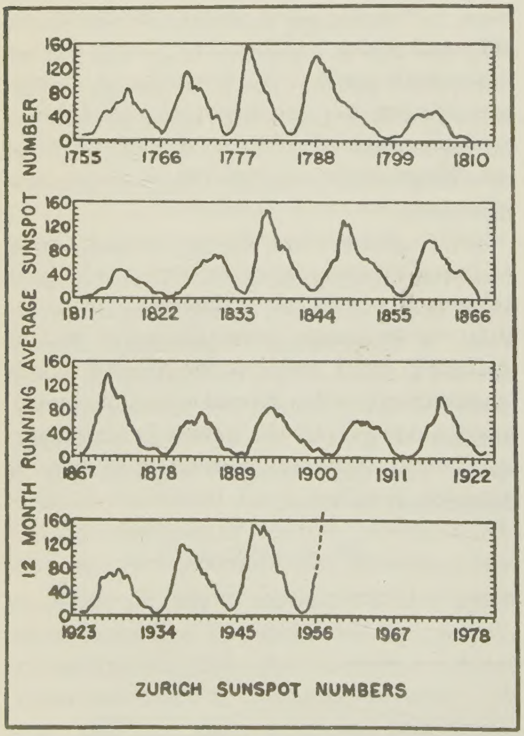

Fig. 1.

It should be pointed out, however, that the IGY was designated as far back as the closing years of the previous sunspot cycle and that considerable solar activity takes place during the entire period of maximum. For individual months the unsmoothed values range widely: there were no sunspots at all observed in January 1954, while in June 1957 the sun was very active and the count reached 205.6.

As in Herschel's time, sunspots are still little understood. They appear dark but only in contrast to the surrounding photosphere; the temperature of the spots can be as low as 4500°K, or 1500°K less than that of the surface. Small spots sometimes occur alone, but rarely last for more than a few days; some large groups cover a few billion square miles and may last for a considerable number of solar revolutions.

The sunspots themselves vary greatly in size, from those large enough to be visible without a telescope, giants as much as 50,000 miles in diameter, to the very small ones, specks only 500 miles across.

Sunspots are not known to occur at solar latitudes higher than about 45°. During periods of least solar activity, small spots form at the larger "allowed" latitudes; as the activity builds up, the spots grow in size, forming at lower and lower latitudes until, during maximum, most of the spots are within plus or minus 10° of the solar equator.

The magnetic fields of sunspots are undergoing concentrated study. Fields have been observed as great as 4000 gauss, or 8000

times that of the maximum intensity of the earth's field at its surface. It has also been noted that sunspots often occur in pairs in an east-west symmetry and it has been found that for a particular cycle the fields will have a uniform distribution of polarity; that is, if the easternmost spot has a north polarity, its western dual has a south polarity. In the opposite hemisphere, the relationship is reversed, and in the subsequent cycle the entire pattern will be reversed.

Many solar phenomena are associated with sunspots, although the mechanisms involved are a matter of conjecture only. Flares are ejections of very hot and active material from the sun's surface accompanied by intense radiation of hydrogen light from the Balmer and Lyman line series far out into the ultraviolet and X-ray region below 100Å wavelength. They always erupt from sunspot regions or regions of very recent spot activity. On the other hand, the prominences, which originate at higher levels, do not always occur in association with spots. When ejective prominences occur on the solar limb, they are a most impressive phenomenon, shooting material some hundreds of thousands of miles out into the corona at speeds sometimes greater than 500 miles/sec. Recent motion pictures of prominences and arches at the limb indicate the influence of magnetic fields on the motion of the prominence gases. At times it seems as if the supporting forces are insufficient, so that the prominences and arches materialize above the solar surface and then fall back into the surface.

When the surface of the sun is photographed through a narrow band filter in the light of highly ionized calcium, the solar disc is mottled in appearance; large disturbed areas, called plages, are apparent. Plages probably are disturbances in the chromosphere, at higher levels than the sunspots, and the plages, like flares, usually occur in association with sunspots.

It is known that magnetic activity in the earth's field varies with the sunspot cycle, although the exact relation between individual spots and magnetic storms remains obscure. Some magnetic disturbances, or "storms," occur when no very active solar region is visible, while the greatest sunspot ever observed in recent history, which was about six billion square miles in extent, produced no identifiable magnetic activity on earth. During parts of the sunspot cycle when activity is low, a twenty-seven day periodicity is noted in the minor magnetic disturbances of the earth's field, indicating a definite relationship between as yet unidentified regions on the sun, perhaps associated indirectly with sunspot groups, and the terrestrial effects.

The spots are under continuous surveillance by solar astronomers in a vigorous program and there is little need for augmentation of the observations during the IGY. Related to the daily observations of the spots, however, is the IGY International Flare Patrol, which is a program to observe and photograph the flares in the light of Hydrogen Alpha (6563Å wavelength) for the purpose of maintaining a continuous study of the sun's activity and to secure information necessary to predict great magnetic storms and other terrestrial effects associated with solar outbursts. During the IGY, the magnetic fields of the sun will be studied in great detail at the Mount Wilson Observatory, with a special electronic instrument, developed by the Babcocks for observing Zeeman splitting, in an effort to learn as much as possible about the relationship of the magnetic field to various surface and chromospheric disturbances, such as sunspots and flares.

The IGY Research Rocket Program

In the United States, the rocket research of Robert Goddard, extending over nearly two decades, 1920 to 1940, helped pave the way for later rocket development. The German V-2 rocket developments of World War II provided a technologic basis for subsequent applications. The development of rockets specifically for upper-atmosphere research was undertaken in the United States by laboratories in the Department of Defense and associated universities. For example, there was the development of the Aerobee and the Viking and, more recently, techniques which carry rockets aloft by balloon before the actual rocket launching. High-atmosphere research rockets in the United States and elsewhere in recent years have yielded significant fundamental data and have established a foundation for new departures in upper-atmosphere research. The advances in the past decade or so have been so rapid, in fact, that the International Geophysical Year has seen the first earth satellite, set on orbit by a rocket.

Types of Rockets

The USNC-IGY rocket program includes the firing of some 194 rockets. In addition, twenty-nine pre-IGY test rockets were fired. Five types of rocket are being used:

The *Aerobee-Hi* is a liquid fuel rocket, using a mixture of nitric acid and alcohol. It carries a payload of 150 pounds in a four- to six-cubic-foot space to altitudes over 150 miles.

For certain experiments which do not require the very high altitude attained by the Aerobee-Hi, a standard *Aerobee* is used to carry a payload of 150 pounds to an altitude of about 60 miles.

The *Nike-Cajun* carries a payload of 40 pounds to an altitude of 100 miles and uses a solid propellant. The *Nike-Deacon*, or Dan, also uses a solid propellant to carry a payload of 40 pounds to an altitude of 75 miles. In both of these rocket systems, the Nike is used as a booster.

The *Rockoon* is a Deacon rocket carried to an altitude of 70,000 to 80,000 feet by a "Skyhook" balloon before the rocket is fired. It carries a payload of 40 pounds to an altitude of 60 miles.

Many rockets will carry out several experiments, so that the total number of rockets does not give an accurate picture of the scientific importance of this program. For example, there are three types of experiments involved in shipboard rockoon launchings from the Arctic to the Antarctic. In the first, rockoons carrying cosmic ray equipment will be launched about every five degrees of latitude in order to obtain a cross-section of cosmic ray intensity at various geomagnetic latitudes. In the second experiment, rockoons are to be sent into the ionosphere in the region of the geomagnetic equator to make direct observations of the presumed equatorial current. The third group of experiments involves the study of so-called soft radiation above 50 kilometers in the southern auroral zone. This will be coordinated with simultaneous observations in the northern auroral zone.

Launching Program

The major effort of the US-IGY rocket program will be centered at Fort Churchill, Canada, where an important new rocket launching installation has recently been completed through the cooperative efforts of the Canadian and US National Committees for IGY and the defense establishments of both countries. Other US rocket launching sites are at Holloman Air Force Base, New Mexico; White Sands, New Mexico; Pt. Mugu, California; Guam; and shipboard.

Table 1 shows IGY research rocket firings.

Rocket Experiments

Considerable technical ingenuity is required to devise measuring systems which can achieve their objectives without temperature, wind, and other distortions result-

ing from environmental factors caused by the rocket's own flight. Thus, an elaborate mechanism is required to provide a stable platform from which to obtain solar spectrographs aboard a spinning, yawing rocket. Atmospheric measurements must be protected from gasses exuded from the pores of the rocket's metal sides in high altitudes, surrounding it with an atmosphere of its own making.

A brief description of the rocket experiments follows:

Meteorology: Atmospheric structure—pressure, temperature, and density of the atmosphere at different levels—is determined by aerodynamic means from pressures measured at various positions on the rocket surface. Photon counters are used to measure solar X-ray penetration into the atmosphere, from which pressure in and above the E-region of the ionosphere may be determined. Another experiment is based on the use of grenades which are ejected from the rockets and exploded in the upper atmosphere. By measuring the transit times of the sound waves from the exploded grenades, atmospheric temperatures and winds between 30 kilometers above the earth and the E-region can be determined. Again, by measuring the drag on spheres ejected from a rocket the density of the D-region of the ionosphere can be found. The optical horizon is located by means of high altitude photographs.

Solar Activity: During periods of marked solar activity, such as solar flares, particular efforts are made to study solar radiations and the sun's spectrum. Photon counters measure the solar radiations in various wavelengths, from the near ultraviolet to hard X-rays. Spectrographs and sunfollowers are used to study the sun's spectrum to wavelengths short enough to include the Lyman beta line of hydrogen.

Airglow: In the airglow experiments, photon counters are employed at various wavelength regions in the visible spectrum. Photomultiplier tubes and appropriate filters are also utilized. OH bands in the near infrared are measured.

Aurora: Geiger counters, proportional and scintillation counters, ionization chambers, and electrostatic analyzers are being used to measure auroral particles. The ultraviolet fluorescence of the atmosphere during the aurora is also being measured by rockets.

Ionospheric Physics: Three principal methods are used to determine ionospheric charge densities. In the first, the delay time of an electromagnetic pulse sent from the ground to a rocket and back is measured; the second uses a phase shift between two harmonically related signals transmitted from a rocket in the ionosphere to determine the index of refraction in the vicinity of the rocket; the third method seeks to determine charge densities from the effect of the ionosphere on DOVAP (Doppler, velocity, position) signals.

The distribution of ozone through the upper atmosphere is determined from rocket solar spectrographs. The chemical and ion composition of the high atmosphere is being studied by a radio frequency mass spectrometer.

Winds between the stratosphere and the E-region are determined through the ejection and explosion of grenades described above. There will also be an effort to determine atmospheric winds by aerodynamic measurements on the rockets themselves.

Geomagnetism: Both standard and proton precessional magnetometers are being employed to measure the earth's magnetic field. An attempt will be made to use these measurements to locate ionospheric and auroral current flows. The magnetometers will permit measurements of field strength within 10^{-4} gauss and component direction within a few degrees.

Cosmic Rays: Low-energy cosmic rays as a function of geomagnetic latitude are measured by geiger counters and ionization chambers and their fluctuation in intensity will be correlated with solar and magnetic phenomena.

TABLE 1

Location	Type & Number	Experiment	Instrumentation	Agency*
Churchill	Aerobee (33) Nike-Cajun (43)	Charge density in ionosphere	Doppler, velocity, and position (DOVAP); rocket borne pulse transmitter; rocket-borne CW transmitters	NRL; AFCRC
		Pressure, temperature, density	Ionization gauges	NRL; AFCRC
		Auroral particles and magnetic field	Proton precessional magnetometer; photo-multipliers, photon counters, and filters; particle counters and spectrometer	NRL
		Chemical and ion composition	Radio frequency mass spectrometer	NRL
		Horizon study	Camera	BRL
		Magnetic field electron density	Proton precessional magnetometer; DOVAP	BRL
		Water vapor	Infra-red hygrometer	BRL
		Density, temperature	Falling sphere	AFCRC
		Airglow	Scanning spectrophotometer	AFCRC
		Temperature, winds	Grenades, geophones; DOVAP	SEL
		Cosmic ray, auroral radiation and magnetic field	Proton precessional magnetometer; geiger counter and spectrometers; crystal counters; crystal counters and emulsions	SUI
Holloman	Aerobee (6)	Solar ultraviolet spectrum	Sunfollowing spectrograph	AFCRC
		Charge density in ionosphere	Rocket-borne pulse transmitter	AFCRC
		Dayglow	Scanning spectrophotometer	AFCRC
White Sands	Aerobee (3) Nike-Cajun (2)	Charge density and water vapor	Infra-red hygrometer; DOVAP	BRL
		Charge density and magnetic field	DOVAP	BRL
		Solar ultraviolet spectrum	Sunfollowing spectrograph	NRL
Pt. Mugu	Nike-Deacon (14)	Solar ultraviolet and X-ray during flares	Photon counters and ionization chambers	NRL
Guam	Nike-Cajun (8)	Temperature, winds	Grenades, geophones; DOVAP	SEL
Shipboard	Rockoon (85)	Soft particle radiation; cosmic ray intensity, magnetic field	Geiger counters and spectrometers	SUI

* *Agency Code:* AFCRC = Air Force Cambridge Research Center. BRL = Ballistic Research Laboratory. NRL = Naval Research Laboratory. SEL = Army Signal Engineering Laboratory. SUI = State University of Iowa.

Pre-IGY Rocket Firings

The US-IGY rocket program has been brought to a high state of readiness through enormous effort on the part of the scientists, technicians, military personnel, and laboratories involved in the program.

During the summer and fall of 1956, pre-IGY rocket firings were conducted by participating agencies. These firings, to test the rockets, their experiments, launching facilities, and general operations at the sites selected for use during IGY, took place at the White Sands Proving Ground, in the Pacific Ocean off San Diego, California, in the North Atlantic Ocean, and at Fort Churchill, Manitoba, Canada.

The rocket firings at Fort Churchill, Canada, represented the major effort. However, the other pre-IGY firings were vitally important to the program and are reported briefly below:

Seventeen rocket firings took place at loca-

tions other than Churchill; ten Rockoon firings were made from a vessel of the U. S. Navy stationed off the coast of San Diego, California. The firings were conducted by the Naval Research Laboratory July 17–27, 1956. Each Deacon rocket carried solar ultraviolet and X-ray detectors.

Two Nike-Cajun rockets were fired at the White Sands Proving Ground during August 1956. One was instrumented for the study of pressure, temperature, and density by the University of Michigan for the Air Force Cambridge Research Center. The second was instrumented by the Ballistic Research Laboratories for the study of charge density in the upper atmosphere. Both rockets were also tests of the new Nike-Cajun two-stage rocket research vehicle. Each of the firings was a success; the rockets reached predicted altitudes in the range of 90 to 100 miles, and the desired information was obtained on the performance of the prototype instrumentations.

Five Nike-Cajun rockets were fired from shipboard between the East coast of the United States and Greenland in the fall of 1956. These rockets contained the falling sphere experiment for the measurement of atmospheric density. This experiment was prepared for the Air Force Cambridge Research Center by the University of Michigan, and is an exact prototype of the one to be flown during the IGY at Fort Churchill.

At Churchill, rocket firings required the installation of complete range and launching facilities. The launching complex itself consisted of an Aerobee tower, movable 10° in any direction to compensate for winds, a building to house the Nike-Cajun (or Dan) launcher, preparation buildings, telemetering trailers, a blockhouse, a generator building, a helium building, and connecting tunnels.

Installed at various places throughout the military reservation at Fort Churchill were numerous instrumentation sites. Included were a five-station DOVAP system and ballistic cameras, installed and operated under the direction of the Ballistics Research Laboratory; two telemetering trailers and an ionosphere station installed and operated under the direction of the Naval Research Laboratory with the assistance of personnel of the New Mexico College of Agriculture and Mechanic Arts; and a network of sound ranging geophones installed and operated by the Army Signal Engineering Laboratory. Also included, installed and operated under the supervision of the White Sands Signal Corps Agency, were two radars, range safety plotting boards and a command transmitter, a frequency monitoring station, a timing system, meteorological and wind ballistic balloon launching facilities and sites, and a complete range communication system.

The pre-IGY rocket program was highly successful from both rocket and instrumentation standpoints; the experience gained will contribute substantially to IGY efforts. The entire program itself was made possible only through the help and cooperation of the Department of Defense, and, in the case of Fort Churchill, the Canadian Government. The program has been materially aided by the Special Committee for the IGY (SCIGY) of the Upper Atmosphere Rocket Research Panel; this is also the operational working group of the USNC Technical Panel on Rocketry, as the three-service, Army, Navy, and Air Force, cooperative effort.

IGY Antarctic Weather Central

The establishment and maintenance, by the US National Committee, of an IGY Antarctic Weather Central to collect and disseminate Southern Hemisphere weather information, particularly for the Antarctic region, was recommended and approved at the First CSAGI Antarctic Conference, held in Paris, July 6–10, 1955.

The basic program at Weather Central involves the reception and recording of weather data from many contributing sources; preparation and analysis of meteorological charts, maps, graphs, and cross sections—mostly synoptic; and broadcasting of current weather information and analyses for forecasting use by stations throughout Antarctica and the remainder of the Southern Hemisphere. Research and training programs are also included, especially during the Antarctic winter months when the general decrease in field activity limits the need for forecasting. In addition, Antarctic Weather Central analyses will be co-ordinated with the IGY World Weather Map series.

Facilities for the Weather Central were fully installed by February 1957 in the meteorology building at IGY Little America Station. At present, the Weather Central staff consists of four US meteorologists and one each from Argentina and the USSR. These participate equally in the program, sharing in the shift work, assisting in processing data, preparing charts and maps, and making analyses and forecasts.

The staff will be increased from six to seven for the next Antarctic winter—three from the US and one each from Argentina, Australia, France, and the USSR. Three additional meteorologists, one each from Belgium, South Africa, and the US, will be added during the Antarctic summer of 1957–1958.

The meteorological information obtained from reporting stations includes standard surface data and upper-air observations from rawinsonde, radiosonde, and pilot balloon ascents. Most Antarctic weather information is received by manual CW radio at the Williams Air Operations Facility, at McMurdo Sound about 400 miles to the east, and transmitted to Weather Central by radioteletype. In order to minimize man-made interference at Little America and to improve capabilities for reception of international weather broadcasts from South Africa, South America, Australia, and New Zealand, the transmitters for the Antarctic mother-daughter communications network and for the US and New Zealand circuits were installed at McMurdo. The circuit between Little America and McMurdo has been reported quite reliable on a 24-hour basis.

Weather data reaches Weather Central daily from all mother stations. Reports from the Australian-IGY Mawson Station are transmitted to the USSR-IGY Mirny Station, for relay to Weather Central. Mirny also relays data from the Kerguelen Island Station (Fr.). Weather reports from Australia and New Zealand arrive via standard international meteorological broadcasts. Reception of similar broadcasts from South Africa and South America has not come up to expectations although South African data is received sporadically by relay from Mirny, and South American reports are received through the O'Higgins (Chile) and Decepcion (Arg.) Stations. Work is being done to improve communications with the Norwegian stations and the Japanese Showa Station.

Meteorological information is also received in the summer season from whaling vessels, and from IGY expedition ships, aircraft, and travelling parties.

Incoming data is utilized, four times daily at present, for the preparation of sea-level charts of Antarctica and surrounding oceanic areas up to 50°S. Charts of the 700-, 500-, and 300-mb levels are analyzed twice a day. Statistical extrapolations from surface charts are being relied upon rather than thickness charts, to give upper-air heights over ocean areas. Adiabatic charts are plotted twice daily for each of the 16 Antarctic upper-air stations, and nine time cross-sections are prepared and analyzed. Continental weather summaries and 24-hour weather outlooks are also issued. Completed analyses and outlooks are compared and correlated with those issued by meteorological stations in Australia, New Zealand, and South Africa, thus obtaining a more complete picture of Southern Hemisphere atmospheric circulation.

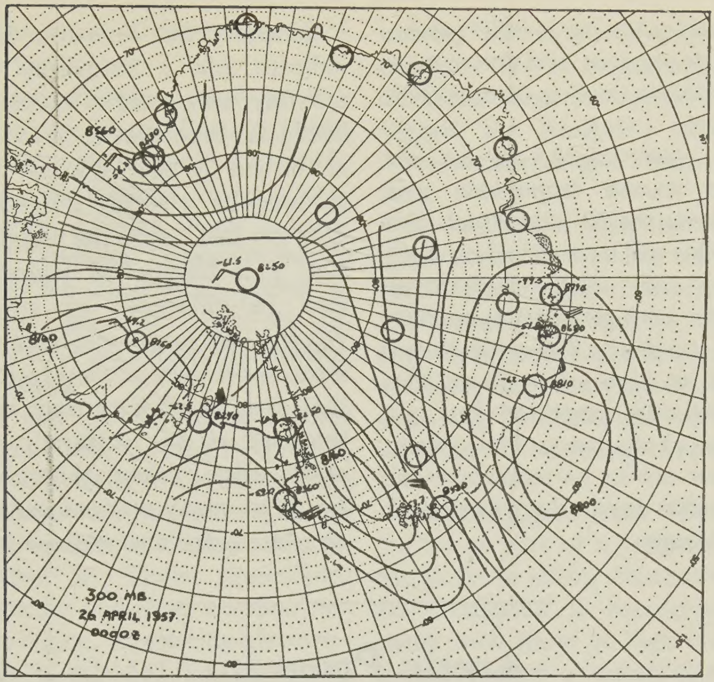

FIG. 2. *Atmospheric circulation at the 300-mb level over Antarctica at 0000 GMT, April 26, 1957, based on Weather Central data. Heights are in meters above sea level; temperatures are in degrees Centigrade; arrows fly with the wind; and wind speed is shown by one full barb for each 10 knots per hour and a filled-in flag for 50 knots.*

Weather Central outlooks are used by meteorologists at the various Antarctic stations as background for on-the-spot local forecasting. Weather Central itself does no forecasting except for a recently begun terminal forecasting program for Little America Station; some regional and route forecasts for scheduled air, sea, and ground operations, as well as for emergency operations, are also made. The Byrd and South Pole Stations have been asked to transmit terminal forecasts, beginning about September 1.

The Weather Central broadcast schedule comprises four weather collective broadcasts daily, at 0415, 1015, 1615, and 2215 GMT, but until recently, all Weather Central analyses have been delayed 24 hours owing to irregular or too infrequent transmission of data from the contributing stations. Transmission schedules are improving, however, and it was expected that by early September, Weather Central would be able to broadcast its analyses about 12 hours after synoptic map time. Weather Central information and analyses are re-broadcast four times daily by the Mirny Station to ensure adequate coverage in the African quadrant of the Southern Hemisphere.

Microfilming of all Weather Central scientific data and records, in order to make a compact, permanent record of them, is now in progress.

During the winter months, when more time is available owing to slackening of activity throughout Antarctica, all IGY Antarctic Weather Central personnel conduct empirical studies to improve understanding of the large- and small-scale features of the Antarctic atmospheric circulation and to attempt to develop improved analysis and forecasting techniques. These studies include weekly discussions, recorded on tape, of synoptic patterns, weather, and analyses, as well as preparation of 10-day and monthly mean charts for meteorological parameters. All notes and conclusions resulting from these studies will be incorpo-

rated in a manual for the use of relief personnel the following summer, and for meteorologists of all nations participating in IGY Antarctic research.

Early IGY observations suggest the existence of a second tropopause over Antarctica between the 50- and 20-mb (19–20 km) levels. This will be watched carefully for confirmation and possible explanation. Evidence has also been gathered apparently confirming the tendency for a deep cold cyclone to exist at high levels above Antarctica, a previously suspected but not directly observed phenomenon. The cyclone, however, appears not to be stationary and evinces considerable day-to-day variation in location and intensity.

Records from Antarctic icecap stations indicate that a temporary rise in mean monthly temperatures usually follows the initial big drop that comes with the setting of the sun for the Antarctic winter. This is followed by a steady decrease, reaching a final low just before the reappearance of the sun. This unexpected temperature regime may be influenced by cloudiness, wind velocity, the large-scale circulation, or combinations of these or other factors. It is hoped that firm conclusions may be drawn after the end of the Antarctic winter, when observations taken throughout the full season at many stations can be compared, correlated, and analyzed.

Arctic Program

The US-IGY Arctic program includes projects in virtually all scientific disciplines to be studied during the IGY. Observations and experiments are being conducted in solar activity, cosmic rays, ionospheric physics, aurora, geomagnetism, meteorology, glaciology, oceanography, seismology and gravity. Most studies are synoptic in nature, their results ultimately to be compared and correlated with those obtained at stations throughout the rest of the world, particularly in Antarctica.

About 50 US stations, distributed over approximately 150 degrees of longitude, have been established in the Arctic. In addition, aircraft are employed to make some measurements, particularly in meteorology, and instrument-carrying rockets, fired from Fort Churchill, Manitoba, in cooperation with the Canadian National Committee, and from ships in northern waters, are probing the upper atmosphere.

(A report of the scientific programs in progress on the two US-IGY drifting stations in the Arctic Ocean appeared in the July issue of the Bulletin on page 7.)

Aurora

Most IGY auroral observations were scheduled to begin in September 1957, after the onset of the long Arctic night. The two principal objectives of the program are an accurate delineation of the northern auroral zones, along with a determination of the periodic variations within these zones, and studies of auroral physics.

The all-sky camera—which utilizes a convex mirror to photograph the entire sky during auroral displays—and auroral radar, are the instruments primarily used to establish the position in space of aurorae. At any given location, the photographic record furnishes information on the type, motion, and integrated intensity of auroral forms as a function of local time. Synoptic maps are being constructed, based on this photographic data; they will indicate the distribution and movement of the auroral forms. All-sky camera installation sites are at Barrow, Bettles, College, Fort Yukon, Farewell, Northway, and Kotzebue, Alaska; Aklavik (tentative), and Knob Lake, Can-

ada; Thule, Greenland; Drifting Station A and Fletcher's Ice Island.

A chain of auroral radar stations is being established along meridional lines in Alaska in order to measure the latitude shift in the auroral zone during displays. Specific locations are Barrow, College, King Salmon, Kotzebue, and Unalaska. Operation was to begin prior to the equinoctial period of maximum auroral activity. Unlike the all-sky camera, radar is not limited by weather and light conditions.

A profile of spectral features of aurorae along a meridional line, showing the production of auroral luminosity of the atmosphere by primary protons, will be obtained by use of patrol spectrographs at College, Alaska; Drifting Station A; Thule, Greenland; Saskatoon, Canada; and other stations outside the Arctic region. A scanning spectrometer at College is expected to provide information on the rapid changes of the auroral spectrum during periods of high geomagnetic activity. Riometers, recently designed to make high-accuracy continuous measurements of the relative ionospheric opacity, using the cosmic noise method, have been installed at College, Barrow, Farewell, Ft. Yukon, King Salmon, and Unalaska, Alaska; Knob Lake and Meanook, Canada; Thule, Greenland; and Kiruna, Sweden.

Cosmic Rays

The IGY program for cosmic ray study involves exploration of the variations in mass and energy of the primary spectrum of cosmic radiation and recording of variations in cosmic radiation intensity at the surface and at altitude. Because the low-energy cosmic rays can reach the earth's atmosphere in the region of the magnetic poles, many cosmic ray studies must be conducted in Arctic and Antarctic areas. The relation of low-energy cosmic ray primaries to high-energy auroral primaries particularly warrants study.

Comparison of cosmic ray data from both polar regions provides information on the isotropy of cosmic rays in space and the character of the geomagnetic field at great distances from the earth. Recent findings suggest the possibility of an asymmetry between Arctic and Antarctic cosmic-ray data.

In connection with the cosmic ray program, a neutron monitor telescope has been installed at College, Alaska, and is now in continuous operation. A second neutron monitor is under construction for installation at Thule, Greenland. A meson telescope, also to be used at Thule, has been shipped and is expected to be installed and in operation shortly.

Balloon flights from Thule will be conducted as part of a program to investigate the latitude effect, fluctuations in the primary radiation in equatorial regions compared with those at high latitude, and the general picture of cosmic ray phenomena at high altitudes at this phase of the solar cycle compared with other phases. During the balloon flights, supplementary ground observations with the meson telescope and geiger counters will be made at the launching sites and at intermediate positions. Long-duration balloon flights from Manitoba will measure fluctuations in primary cosmic-ray intensity. Photographic emulsions carried by balloons will be exposed at high altitudes to collect data on the energy range of the primaries and the nuclear reactions they induce.

The unusually long path traversed by solar radiation in the Arctic, similar in length to sunrise-sunset paths in lower latitudes, provides ideal conditions for solar infrared absorption measurements. Such measurements will be made at Thule during the long summer daylight hours. Analysis of the spectra obtained will provide information on the atmospheric concentration of CO, CH_4, CO_2, and other minor constituents in polar regions.

Ionospheric Physics

The Arctic ionosphere is a highly complex region in which the normal ionic layers are

constantly disturbed and distorted by strong atmospheric turbulence, auroral currents, and appreciable fluxes of incoming particles. An understanding of the nature of these motions and an adequate description of the polar ionosphere are lacking. Because the day-night cycle, complete in 24 hours elsewhere, requires 12 months near the pole, the study of the polar upper atmosphere offers the solution to many ionospheric mechanisms, permitting detailed study of the rate of absorption of electrons during the long polar nights, and the rate of ionization during the polar day.

Ionospheric soundings during the IGY will also provide information on the equivalence of ionospheric characteristics in the two polar regions, and on the three-dimensional form of the earth's magnetic field. The new IGY station at Thule, Greenland, less than 2° from the north geomagnetic pole, has already obtained many soundings verifying the conventional picture of a vertical magnetic field at great heights over the geomagnetic pole.

In the US-IGY Arctic program, vertical incidence soundings using standard sweep-frequency equipment (1 to 25 mc/sec in 15 seconds) are being made at Adak, Anchorage, College, and Barrow, Alaska; on Fletcher's Ice Island; in cooperation with Denmark, at Thule, Narsarssuak, and Godhavn, Greenland; and, also cooperatively, at Reykjavik, Iceland. A fixed-frequency backscatter instrument at College has been in operation for several months, and similar equipment at Thule, and at Knob Lake and Meanook, Canada, began operation by July 1, 1957. A sweep-frequency backscatter station at Knob Lake begins operating in the fall of 1957.

During the IGY, twelve Arctic transits will be made by airborne recorders. Virtual height measured against frequency reflections will be continuously obtained. Later analysis will give a determination of the drift direction of the ionosphere. Wherever possible, the aircraft will fly over ground-based vertical incidence sounding stations.

Whistlers, radio signals of descending pitch initiated by lightning discharges and developed by dispersive propagation of sferics over very long extra-atmospheric paths, are being studied synoptically by a network of US-IGY stations in Arctic areas and elsewhere in the Western Hemisphere. Equipment is already installed and operating at Arctic stations at Anchorage, Unalaska, and College, Alaska, and at Knob Lake, Canada; additional stations are planned for Nome or Kotzebue, Alaska; Godhavn, Greenland; and Father Point and Frobisher Bay, Canada.

Radio noise recording equipment at Thule was expected to be in operation by August 1957. These studies of the naturally occurring radio signal pulses arising from lightning discharges will provide additional information about the characteristics of the ionosphere, as well as about thunderstorm incidence.

Geomagnetism

The main emphasis of the IGY geomagnetic program is on a series of observations and experiments designed to yield data on the rapid fluctuations of the earth's magnetic field. These variations, which make up a relatively small part of the earth's generally stable magnetic field are most frequent and strongest in polar and equatorial regions; a large part of the IGY effort in these studies is, therefore, being made in the Arctic. As one of the three hypothetical great upper atmosphere electrical currents that give rise to these fluctuations coincides with the northern zone of maximum auroral frequency, a network of stations has been established in Alaska transecting this zone. Surface magnetic data will be supplemented by data from rockets and earth satellites, by radio wave propagation data, and by data from ionospheric, auroral, and solar observations.

Five Alaska stations—at Sitka, College, Point Barrow, Healy, and Big Delta—and two sets of sub-stations, or slave stations, attached to the College station are now

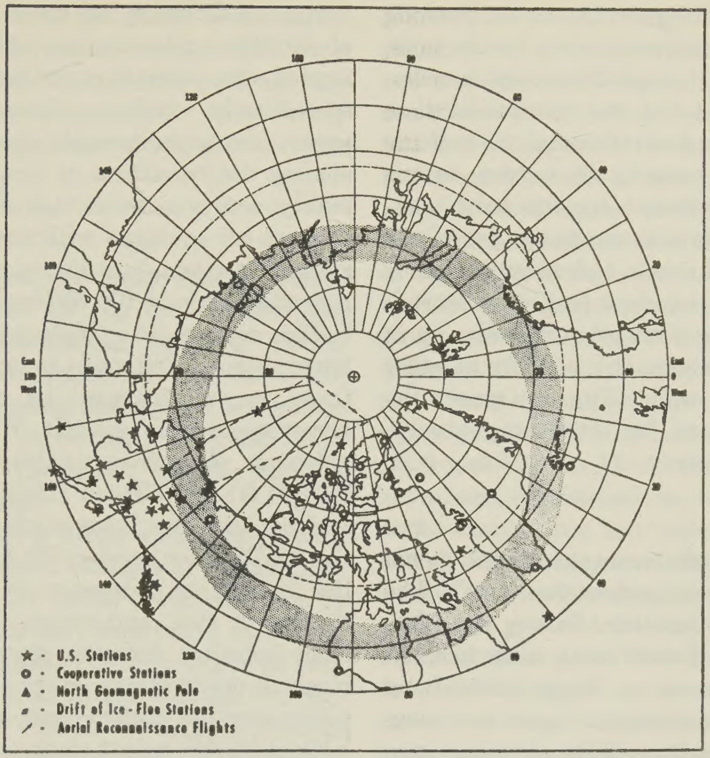

FIG. 3. *US-IGY Arctic Region Stations. Dark band is zone of maximum occurrence of auroras. Path of reconnaissance flights is sometimes varied or reversed to obtain wider coverage or to adjust to changes in weather conditions.*

equipped with Ruska rapid-run magnetographs and standard magnetographs of normal and low sensitivity; all have begun operations. The Healy, Big Delta, and two of the satellite stations are new; the others were operating prior to the IGY.

The College station is also operating a newly devised differential magnetograph. This consists of a central recording instrument at the U.S. Coast and Geodetic Survey observatory, near Fairbanks, connected by electrical cable to instruments at two slave stations about 7 miles away in the magnetic south and west directions. Measurements obtained will make it possible to compute the intensity and location of the ionospheric electrical currents that are presumed to be responsible for disturbances in the magnetic field.

Askania 3-component variographs are in operation at all stations of the north-south trans-auroral Alaska network and on Drifting Station A. The network, consisting of stations at Anchorage, Kotzebue, Northway, Fort Yukon, and Barter Island, will provide information about ionospheric currents affecting the local geomagnetic field. A transit magnetometer, fitted with a deflection magnet for H observations, will be installed on Drifting Station A.

Visual magnetic variometers will be installed at Barrow and College, Alaska, and at Thule, Greenland, to provide hour-by-hour information on disturbances in the magnetic field. Thule and College will also receive instrumentation to record magnetic fluctuations in the 1- to 50-cycle frequency range. The measurements will be compared with similar data obtained in middle latitudes.

Solar Activity

Tentative IGY plans are to establish a station at College, Alaska, for continuous

monitoring of solar activity during the long polar day. During the summer, a radio noise patrol at a frequency of 200 mc/sec is maintained at College, and may be established at other sites. Recordings obtained will indicate the onset and severity of sudden cosmic radio noise absorption by the earth's atmosphere. At low solar angles the patrol will be principally of bursts and noise storms.

Indirect flare detectors to determine sudden cosmic noise absorption will also be in operation at College, and possibly at other locations; they will utilize equipment already in operation for ionospheric absorption measurements.

Meteorology

It has long been recognized that Arctic air masses are an important factor in Northern Hemisphere weather. During the IGY, a concentrated effort is being made through synoptic studies at a large number of meteorological stations to gain a better understanding of the relationships involved among the various factors that make up our weather. Many new stations have been established, especially in polar areas, where the need is greatest, and stations in existence prior to IGY have been improved by addition of new types of equipment.

There are some 18 meteorological stations in Alaska as a part of the IGY Arctic meteorological program; most of them are permanent stations established prior to IGY. Additional stations have been installed on Drifting Stations A and B (the latter on Fletcher's Ice Island) in the Arctic Ocean, and about eight more have been established in Canada and Greenland and are being operated on a cooperative basis. The stations at Thule, Greenland, and the Alert, Eureka, Ft. Churchill, and Resolute stations, in Canada, constitute the northern end of the 70° to 80° W pole-to-pole chain of meteorological stations.

Standard meteorological observations are being made at most Arctic stations. These include continuous recording of surface temperature, humidity, pressure, precipitation, wind direction and speed, and duration of sunshine; pilot balloon observations, as needed for aircraft operations; standard three-hourly surface observations; and twelve-hourly rawinsonde observations, including determination of temperature, humidity, and pressure at high altitudes. Most stations are equipped with newly developed 800-gm rawinsonde balloons, with a height potential of about 100,000 feet.

The surface and high-altitude balloon observations being made at most Arctic stations are supplemented by meteorological observations from aircraft. Weather reconnaissance observations, along the 700-mb (10,000 ft) and 500-mb (18,000 ft) pressure surfaces, are now being made on flights by the Air Weather Service, US Air Force, from the vicinity of Fairbanks to a point near the North Pole, and return. The measurement schedule includes standard meteorological observations every half hour at points over the Arctic Ocean, and dropsonde releases at five points along the flight path. Meteorological elements reported are visibility, weather, turbulence, cloud conditions, temperature, dew point, height of pressure surface, surface and upper-air wind, icing rate, condensation trails, and surface ice.

In connection with meteorological heat and water budget studies, closely linked with related studies in oceanography and glaciology, personnel at Drifting Station A are also making observations of solar radiation, reflectivity of the snow surface, net radiation heat flux, sky brightness, total atmospheric ozone (with a Dobson spectrophotometer), and vertical wind and temperature structure near the ground and, with a wire-sonde, up to a height of 1000 feet. A Dobson spectrophotometer is also in use at the College Station. Six Alaskan stations, including College and Drifting Station A, are also making solar radiation measurements, using the Eppley pyrheliometer.

One early result of IGY Arctic meteorological studies has been the observation by some stations of several instances of high-level warming. Temperature increases from

$-80°$ to $-15°$ C at the 25-mb level, occurring within a period of three of four days, have been noted. Preliminary analysis suggests that this phenomenon is probably caused by large-scale subsidence in the atmosphere.

Oceanography

In addition to the many special studies being conducted on the drifting stations, standard measurements of long period waves, sea level variations, and steric observations are being made at fixed stations at Adak, Attu, Barter Island, Kodiak, Point Barrow, and Unalaska, Alaska, and at Thule, Greenland.

The dynamics of Arctic sea-ice movement, as well as seasonal changes in volume, are being studied by aerial reconnaissance. A number of flights have been made, and under present plans flights are to be made at two-week intervals from March through September 1957, and March through September 1958, usually in conjunction with weather reconnaissance observations by the US Air Force Air Weather Service. Photographic records are being obtained.

A synoptic deep water survey of part of the North Pacific Current, being undertaken this summer by ships of the US, Japan, Canada, and the USSR will include northern waters up to the Aleutians. In the summer of 1958, a longitudinal profile survey to be made by US and Canadian ships will include bathymetry, bottom sampling, and physical and chemical studies as far north as Bering Strait. Particular attention will be given to the deeper waters, below about 8000 feet.

Glaciology

Arctic glaciology during the IGY is concerned with the morphology, history, and mechanics of mountain glaciers, ice sheets, and drift ice, and with the influence of this great volume of polar ice on the meteorology, climatology, and oceanography of the remainder of the northern hemisphere. Synoptic studies of the fluctuations in mass of northern glaciers and Arctic sea-ice are expected to provide clues to past climatic changes and present trends. Study of heat and moisture exchanges across the sea-ice and air-ice interfaces, and of long-range and seasonal accumulation and ablation, are essential parts of this program.

The McCall Glacier in the Brooks Range, the Lemon Glacier, near Juneau, and parts of the Alaska Range, are now being studied by US-IGY glaciological teams. Work in progress on the McCall Glacier, under the direction of R. C. Hubley, represents the first direct scientific study of an Arctic alpine glacier. With equipment and supplies air dropped by the US Air Force, two camps have been established on the glacier. The main camp is in a firn region on the upper part of the glacier, about 8200 feet above sea level, and the second camp is about a mile above the glacier terminus, at an elevation of about 6000 feet. Two men at the high camp are engaged in snow stratigraphy, movement, and micrometeorological observations; two others at the lower camp are conducting surface movement observations and photogrammetric studies. A recent report from the project leader states that it has become clear that all significant snow accumulation on these glaciers occurs during the summer months.

Special IGY glaciological studies are being made on the great continental ice sheet of Greenland by the Snow, Ice, and Permafrost Research Establishment (SIPRE) of the Corps of Engineers, US Army. A 1700-foot drillhole in the ice sheet has shown a temperature gradient of only 0.5°F per 1000 feet, from 24.5° to 25.0°. Such deep holes give further information on the temperature gradient of the ice and on the rate of closing of the hole.

Seismology and Gravity

The US-IGY Arctic programs in seismology and gravity are part of the worldwide IGY effort to gather information on the precise shape, or figure, of the earth; on earth tides; on the structure and seismicity of both the crust and interior of the earth; and on

related phenomena. Sufficient observations and measurements in these disciplines have heretofore been lacking for the polar regions. Accurate determination of the oblateness of the geoid, and the distortion near the geographic North Pole can be made from accurate gravity measurements in the Arctic.

Arctic gravity and seismic measurements will also help greatly in working out the geologic structure of the Arctic Basin. A 10,000-foot submarine mountain range, the Lomonosov ridge, has already been outlined by bathymetric measurements made from ice-floe bases by Soviet scientists, and, separately, by US scientists on Fletcher's Ice Island. More recently, US scientists conducting gravity investigations on Drifting Station A have discovered a 5000-foot submarine ridge paralleling the Lomonosov ridge.

During the IGY, gravity standardization measurements to increase coverage by reliable gravity stations and to provide a number of additional first-order control points for local gravimeter surveys are being made along north-south lines with the Gulf compound quartz pendulum. Pre-IGY measurements in this program have already been made between Fairbanks, Alaska, and Paso Cortez, Mexico. Thule, Greenland, is the northern station of another line extending down the eastern coasts of North and South America to Cape Horn. Still another north-south line of stations will connect the Aleutians with Antarctica, by way of the east coast of Asia and through Australia. The quartz pendulum measurements at these sites will be complemented by measurements with Cambridge University compound, magnetically-compensated Invar pendulums. Pendulum measurements are also to be made at Barrow and Barter Island, Alaska, and cooperatively at the Canadian stations at Alert, Eureka, Mould Bay, and Resolute.

Pendulum ties have already been made to the two Arctic Ocean drifting stations. Throughout their occupation, essentially driftless gravimeters, such as the Frost meter —a zero length spring-type instrument—will be read daily. There will be close coordination between gravity work on the drifting stations and the Geophysical Research Directorate program of oceanographic studies.

Earth tide measurements, which provide a basis for determining the rigidity of the earth's crust and add to our knowledge of the nature and structure of its interior, are to be made for a period of 31 days at the Barrow station.

These observations will be analysed in conjunction with similar determinations by other polar stations.

As part of the US-IGY program, a standard seismographic station has been established at Thule, Greenland. The Thule station is equipped with both vertical and horizontal component instruments. Standard stations at College and Sitka, operated by the Coast and Geodetic Survey, are also supplying seismic data. Observations from these sites will permit more precise determinations of earthquake locations, both within the Arctic and throughout the remainder of the world.

In cooperation with Canada, a long-period seismograph, to be operated by resident personnel, is to be installed at Resolute Bay Station. Dispersion of surface waves over the continents and oceans will be measured.

Arctic stations are also observing microseisms, small crustal vibrations attributed to storms over the oceans or near their borders. Study of the relationship between Arctic microseisms and Arctic and North Atlantic meteorology and oceanography is part of this aspect of the seismology program.

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